International Solar Alliance Expert Training Course

In partnership with the Clean Energy Solutions Center

Dr. David Jacobs

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

INTERNATIONAL SOLAR ALLIANCE

Session 8a: Rate Design

In partnership with the Clean Energy Solutions Center (CESC)

Dr. David Jacobs

Supporters of this Expert Training Series

IET International Energy Transition

INTERNATIONAL SOLAR ALLIANCE

CLEAN ENERGY SOLUTIONS CENTER

ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

IET – International Energy Transition GmbH

Dr. David Jacobs

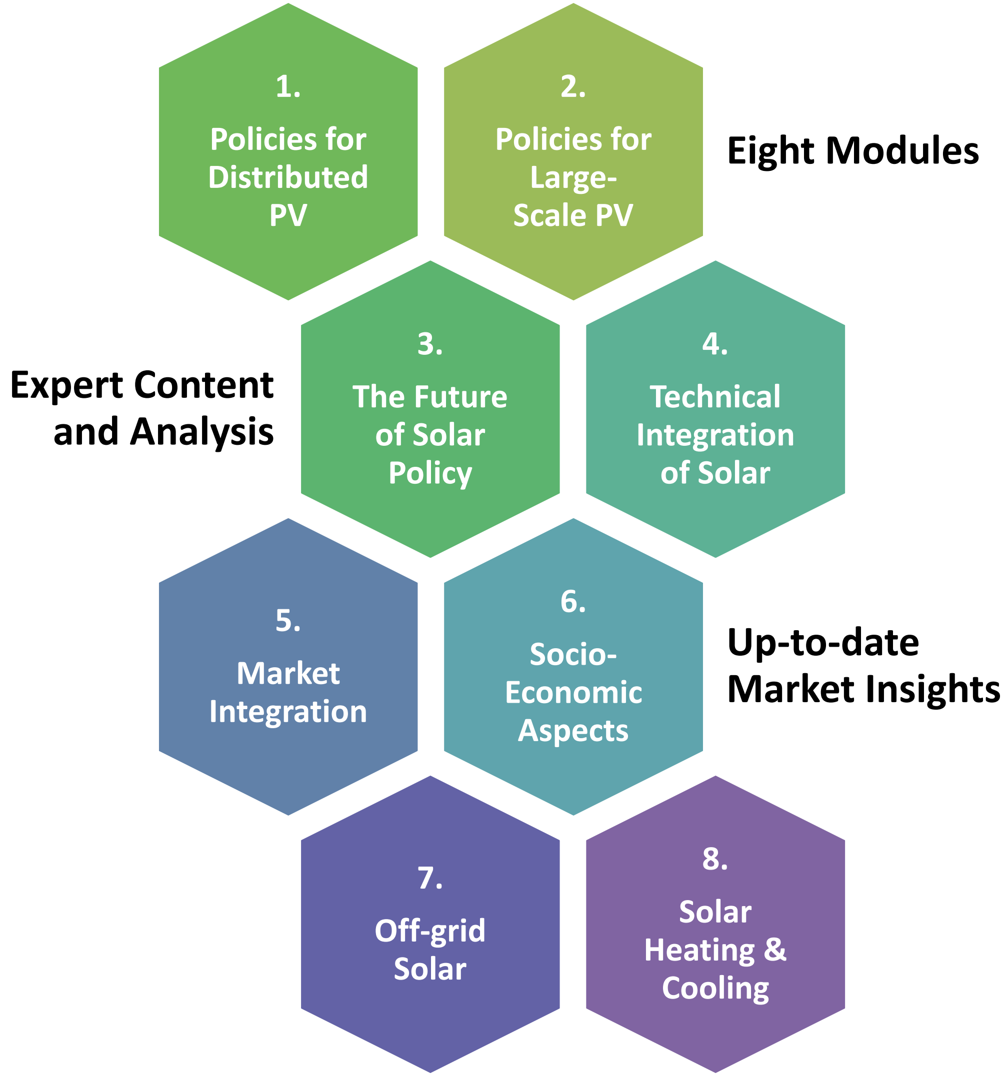
- Founder and director of IET
- Focus on sustainable energy policy and market design
- 14+ years experience in renewable energy policies
- 60+ publications on energy and climate
- 40+ countries work experience (consulting and presentations)

Training Course Material

This Training is part of Module 1, and focuses on Rate Design (2 sessions)

Related training units are:

- ✓ 2. Introduction to Solar Policies: Net Metering, Net Billing, NET-FIT, FITs, and Auctions
- ✓ 3. Solar PV Policy Deep-Dive: Overview of Compensation Mechanisms for Rooftop Solar
- ✓ 6. Solar PV Policy Deep-Dive: Net Billing and Net Metering (and other self-consumption policies)



Overview of the Training Session

1. Introduction: Learning Objective

2. Understanding traditional rate design (volumetric, fixed and demand charges)

3. Outlook for second session on rate design

4. Further Reading

5. Knowledge Check: Multiple-Choice Questions

Outlook: Next Training Session on Rate Design

1. Understanding smart rate design (time-based, locational)
2. Understanding prosumer rate design (two-way rates)
3. Understanding cost-benefit analysis of DG
4. Concluding Remarks
5. Further Reading
6. Knowledge Check: Multiple-Choice Questions

Introduction:

Learning Objective

Learning Objective (I)

- Understand the impact of RE and distributed generation on power systems
- Understand the link between RE deployment and rate design (modifications)
- Understand the fundamentals of electricity rate design (structure of electricity prices)
- Understand classic rate design options and impact on DG/solar (volumetric, fixed and demand charges)

Glossary

Abbreviation	Word	Meaning
AMI	Advanced Metering Infrastructure	Meters and data systems that enable two-way communication between customer meters and the utility
CPD	Coincident Peak Demand	Energy demand by a customer or class of customers during periods of peak system demand.
CPP	Critical Peak Pricing	Pricing scheme where rates are low in off-peak times, but increase substantially when costs spike.
DG	Distributed Generation	Small-scale and modular electricity producing units that are directly connected to the distribution network (hence, closer to the end-user)
LRMC	Long-Run Marginal Costs	The long-run costs of the next unit of electricity produced. Also called long-run incremental costs
NM	Net-metering	Utility billing mechanism that credits residential and business customers who are producing excess renewable electricity and send it back to the grid.
RTP	Real-time Pricing	Pricing scheme where customers pay a rate that is directly linked to the hourly market price. Generally in use for large consumers (industry, commercial users)
ToU	Time-of-Use Rates	A form of time-varying rate, where the cost of electricity varies based on the time of day it is consumed
VRE	Variable renewable energy sources	Wind and solar PV

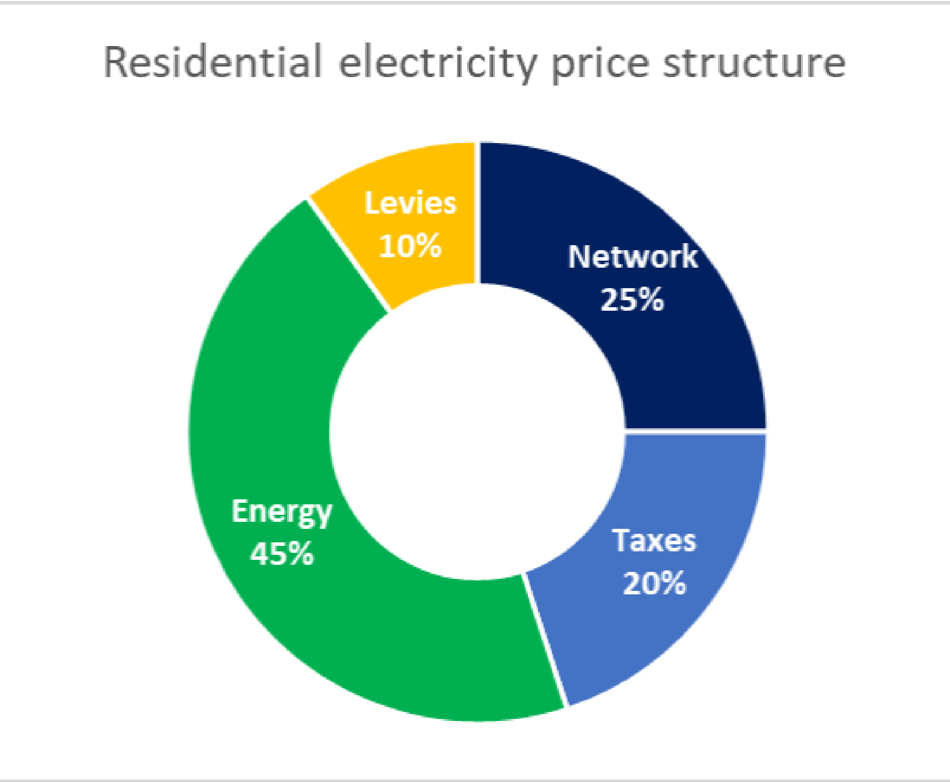
Introduction:

Rate design: Which part is regulated and which determined by the market?

Which part of the electricity prices is subject to rate design?

1. Fully liberalized markets

- Only network costs are regulated (part of rate design)
- Other cost components are either determined by market dynamics (e.g. energy costs) or taxes and levies.



Which part of the electricity prices is subject to rate design?

2. Vertically Integrated Utilities

- Historical rates blended all utility costs into one or a few price variables seen by customers (e.g. fixed and volumetric costs);
- Movement toward greater unbundling of cost and value components (transparency).
- One reason for this is the rise of DG and prosumers (two-way tariffs, cost-benefit analysis of DG)

Source: IET based on Cross-Call, D., et al. (2018)

Generation	Transmission	Distribution	Customer	General Plant & Overhead Expenses
Debt service O&M Fuel Some transmission lines and substations needed to integrate generation resources	Substations connecting transmission lines Lines (towers, conductors, etc.) O&M	Substations connecting distribution lines to transmission or to other distribution voltages Lines (conductors, poles, conduit, etc.) Line Transformers O&M	Service drops Meters Meter reading Billing Customer service	Office space Computers and technology Communications equipment Pensions Legal and regulatory

Source: Whited (2017)

Introduction:

Understanding the Link Between RE Deployment and Rate Design

Understanding the Link between RE Deployment and Rate Design

- Why do rates need to be adjusted once the share of solar energy increases?

  1. Increasing shares of variable renewables in the system (solar PV)

  2. Increasing shares of distributed generation (roof-mounted solar PV) in the system

Introduction:

Features of Future Power Systems and Effects of Increasing Shares of RE

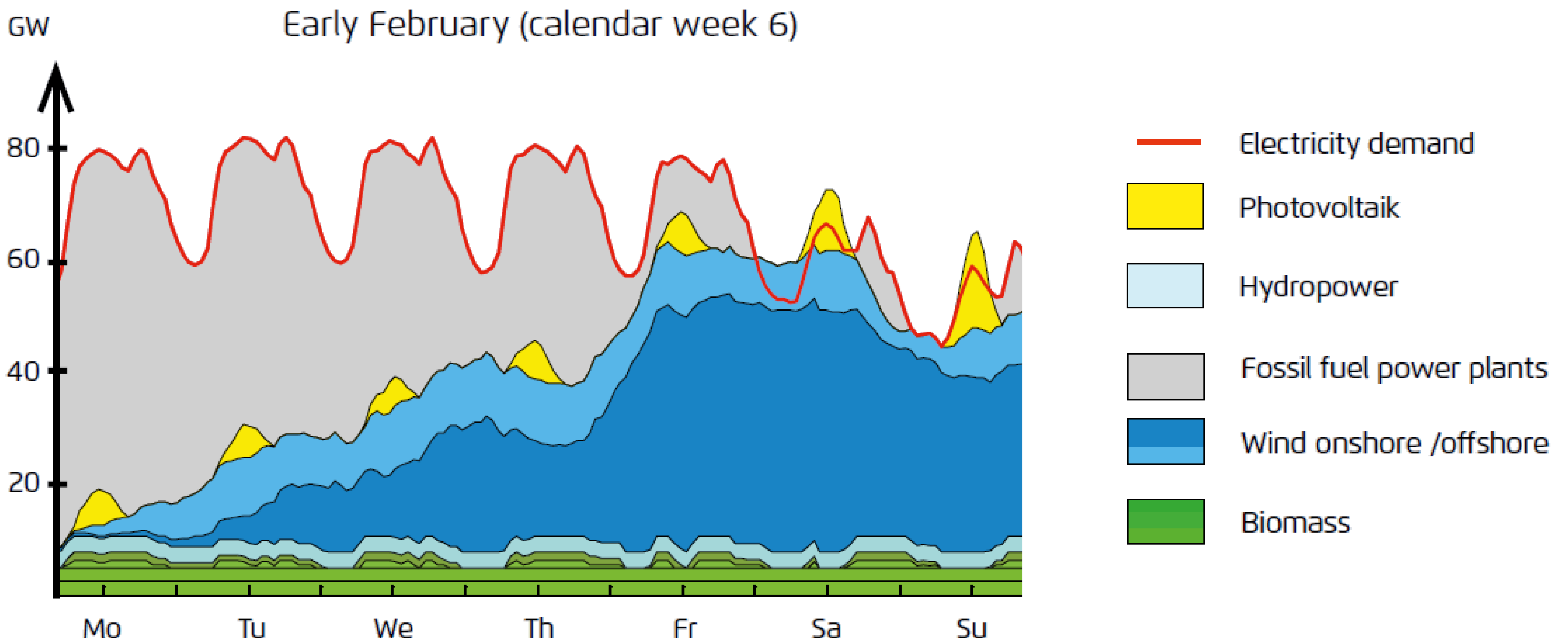
Flexibility is Key

- Future power systems will require high levels of flexibility in order to incorporate high shares of variable renewables

- Flexibility will have to come from the generation side but also from the **demand side**!

The electricity market is determined by wind and solar PV

Electricity demand and renewable power generation in 2022



Source: Agora Energiewende 2012

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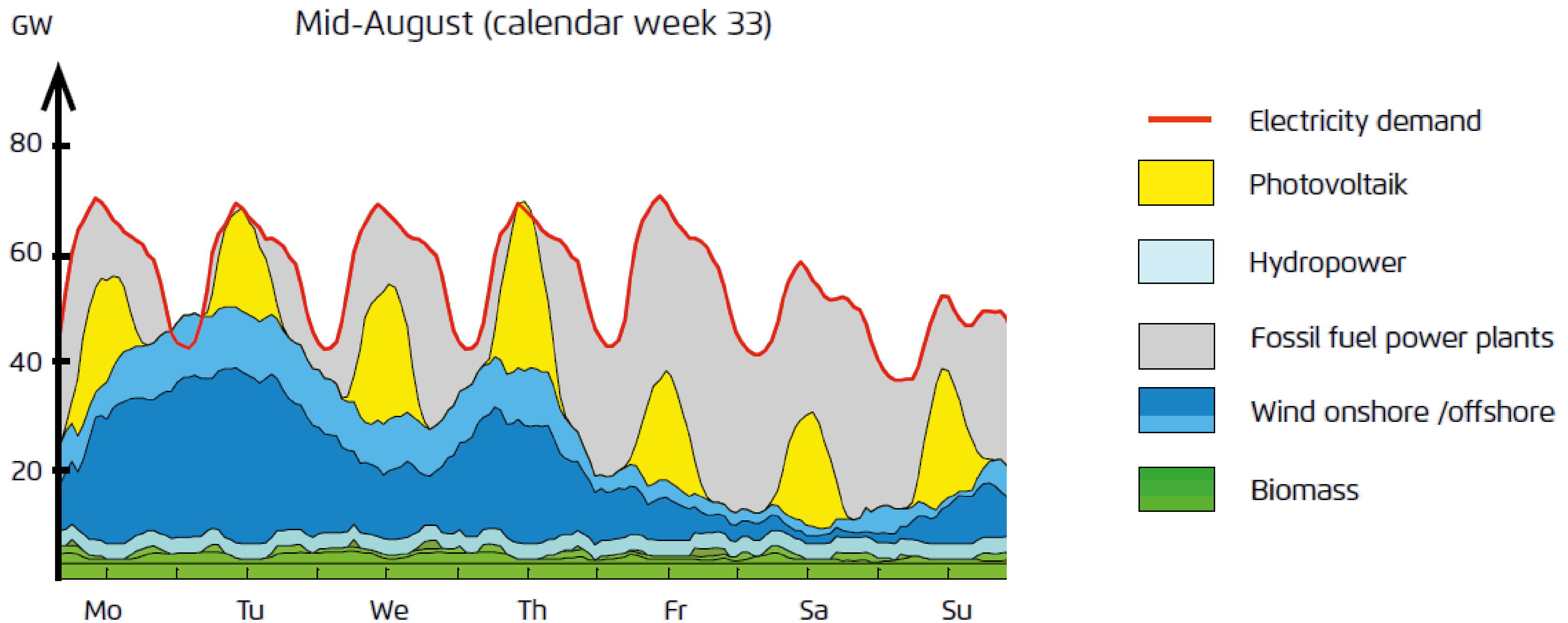

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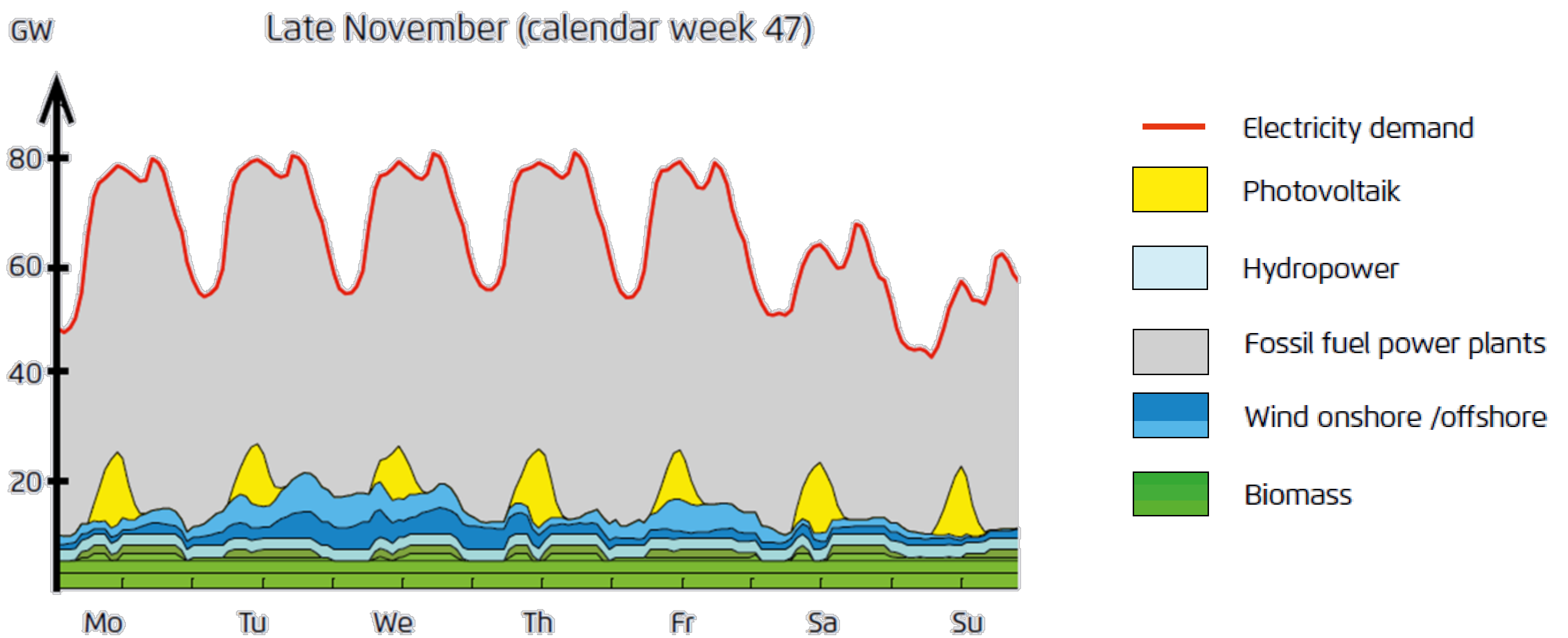


Source: Agora Energiewende 2012

Flexibility is Key

- Sample situations:

  - Hourly, daily, seasonal variations in RE generation, leading to more price volatility on wholesale markets
    - Customers should be incentivized **to react to price variations (price signals)**

  - Time of very low RE penetration, leading to very high prices due to the use of extreme peaking power plants
    - Customers should be incentivize **to use (radically) less electricity**

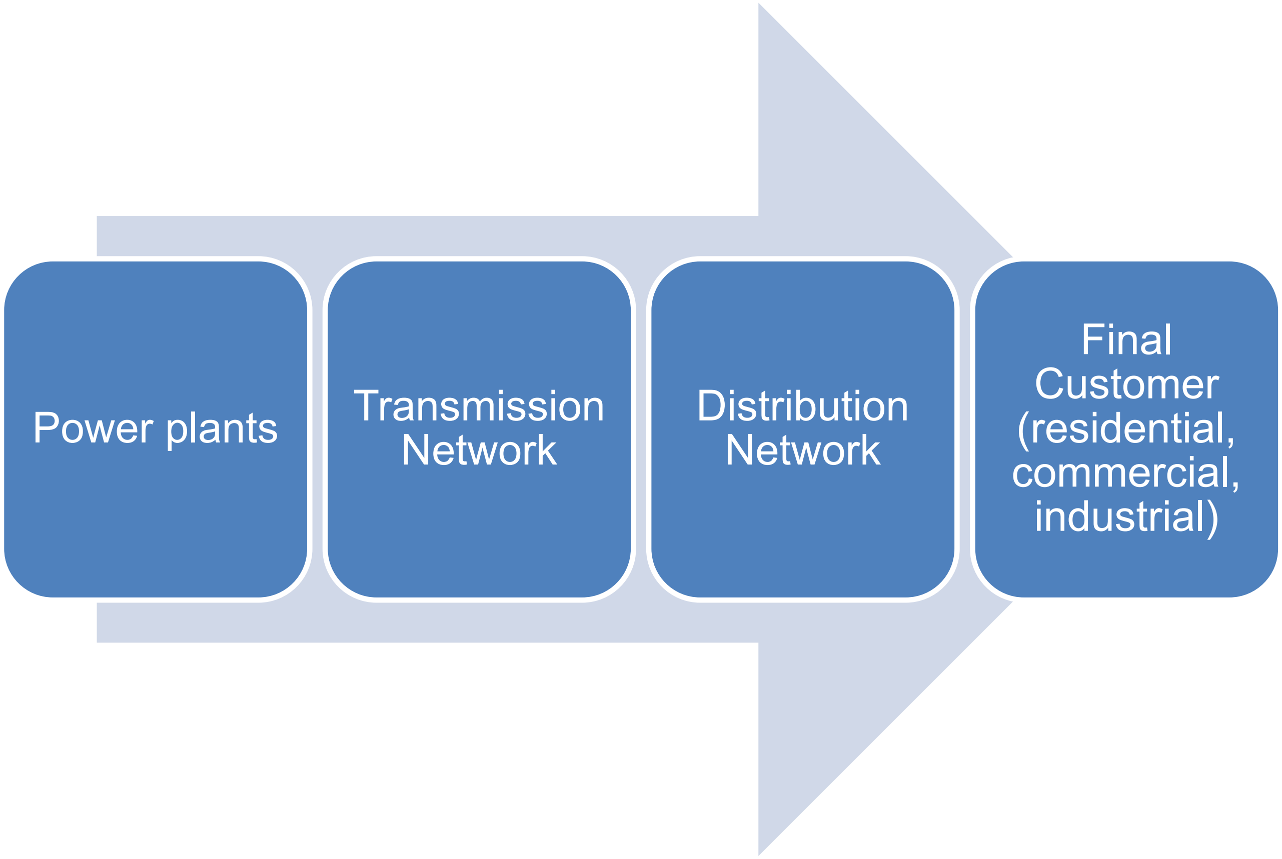
  - Times of excess RE generation (RE generation exceeds total standard demand)
    - Customers should be incentivized **to use more electricity**

Introduction:

Features of Future Power Systems with Increasing Share of Distributed Generation (Prosumer)

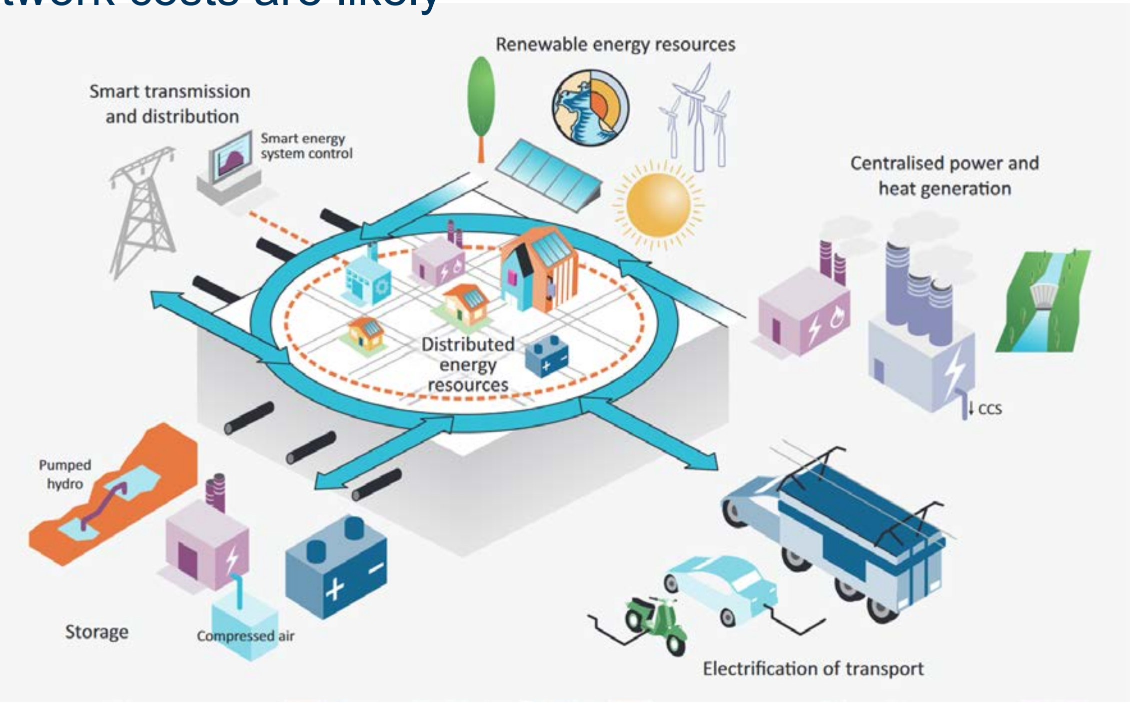
Traditional/Old Power System

- One-way flow of power



Increasing Shares of Distributed Generation

- Need for making distribution networks smarter
  - Two-way flow of power, advanced metering, remote controlled units, etc.
- Need for distribution grid upgrades
  - Distribution grid costs constitute the major share of total network costs (around 80%); Higher network costs are likely
- Need to establish compensation mechanisms for prosumers
  - Net Metering, Self-Consumption, etc.
- Need for rate adjustments in order to incentivize the right behavior



Source: IEA (2014)

Introduction:

Understanding the Objectives of Electricity Rate Design

Traditional Policy Objectives Related to Rate Design

- Enable **cost recovery** (cost of services)
  - To provide reliable services for all costumers

- Assure **cost-efficiency**
  - of the overall power system; effective price signals are needed

Source: IET based on RMI (2016), SEIA (2013), Cross-Call, D., et al. (2018),

Traditional Policy Objectives Related to Rate Design

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- Apply the **cost causation** principle
  - Who uses the grid where, when, to what extent, etc.
- Fair **cost allocation** (among all ratepayers),
  - Consistent with principles of equity and affordability.
- Assure **affordability**
  - Especially for low income households
  - Frequently implies cross-subsidies in developing countries

Source: IET based on RMI (2016), SEIA (2013), Cross-Call, D., et al. (2018),

Emerging Policy Objectives Related to Rate Design

- Incentivize **demand side flexibility** (locational, temporal)

- Incentives for **energy efficiency** and peak **demand reduction**
  - Reduce demand during peak hours

- **Enabling innovation** and integrating **new technologies**
  - Distributed energy technology
  - Energy management technologies

- Balancing **utility** and customer/**prosumer interests**:
  - Consider services provided by the grid and services from the customer

Source: IET based on RMI (2016), SEIA (2013), Cross-Call, D., et al. (2018),

Emerging Policy Objectives Related to Rate Design

- Foster **customer empowerment**:
  - Access to data (customers' power consumption)
  - Provide customer education
  - Provide customers with timely and granular information so that they can make informed decisions about how they meet their energy needs
  - Send customers price signals (e.g., temporal, locational, and customer type)

Source: IET based on RMI (2016), SEIA (2013)

Emerging Policy Objectives Related to Rate Design

- Adopts **long-term perspective** when assessing which costs are fixed (and which variable)
  - Utilities sometimes argue that most costs are fixed (short-term perspective)
  - Economic theory suggest a long-term perspective (only very few costs are fixed)
  - Consumers' decision on electricity usage influence long-term investment decisions
  - Long-term perspective can provide economically efficient price signals

Source: IET based on RMI (2016), SEIA (2013), Cross-Call, D., et al. (2018), Whited et al. 2016

Emerging Policy Objectives Related to Rate Design

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- Apply **gradualism**
  - Changes to rate design should not cause large, abrupt increases in bills
  - Grandfathering: Rate design changes should minimize impact on existing customers (net metering customers should have the right to remain in their existing rate category).

Source: IET based on RMI (2016), SEIA (2013)

Recommendation

- First define the objectives (hierarchy of objectives), then do the rate design calibration!

Introduction:

Traditional Rate Design

An Overview of Rate Design Options

Traditional rates

- Volumetric Charges
- Fixed Charges
- Minimum bills
- Demand Charges

Can be implemented based on **existing meter technologies**

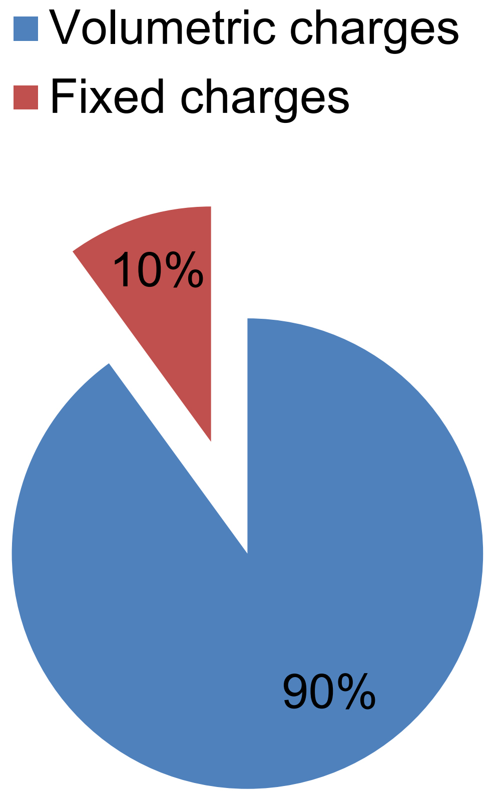
Source: IET based on Cross-Call, D., et al. (2018), Linvill 2014

Rate Design Parameters

Typical electricity bill (for **residential customers**) consist of two components:

- Volumetric charges:
  - Energy related costs (varying with the use of energy)
  - Per unit of consumption (e.g. kWh)
- Fixed charges:
  - Customer related costs (cost for meters, meter reading, billing, etc.).
  - Per billing period (e.g. once a month)

Typical composition of residential bills



Rate Design Parameters

Typical electricity bill (for **commercial and industrial customers**) consist of three components:

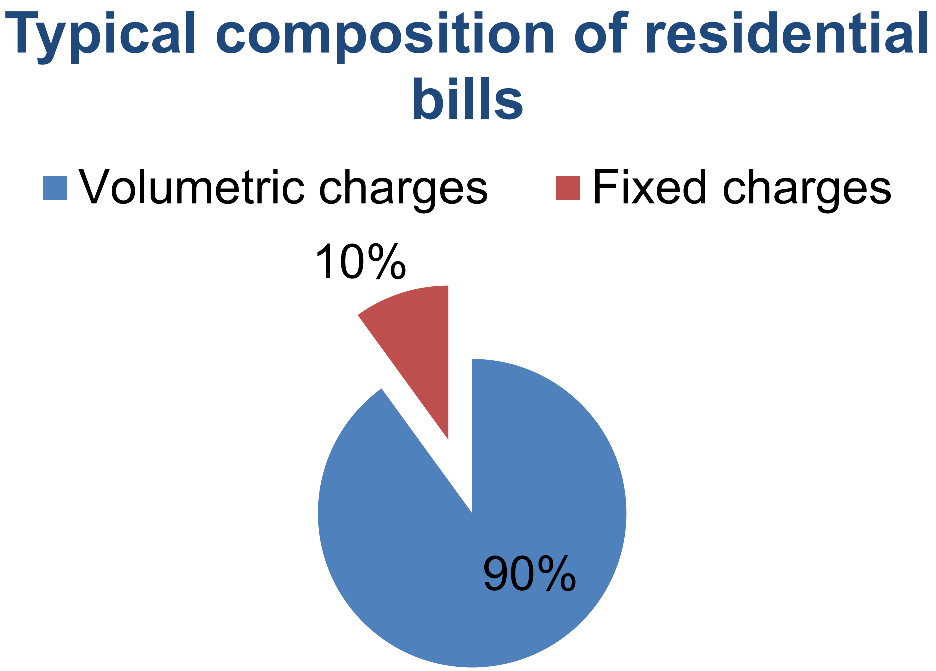
- Volumetric charges:
  - Energy related costs (varying with the use of energy)
  - Per unit of consumption (e.g. kWh)
- Fixed charges:
  - Customer related costs (cost for meters, meter reading, billing, etc.).
- Demand charges:
  - Demand related costs (associated with maximum demand; demand during system peak demand or local peak demand)

Traditional Rate Design:

Volumetric Rate Design

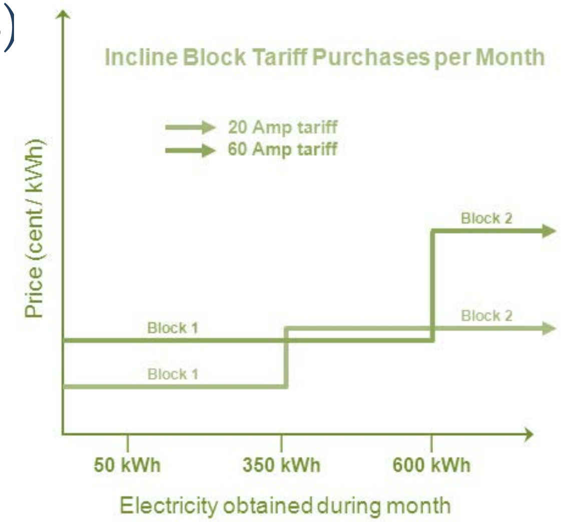
Volumetric Rates

- System costs (e.g. electricity grid) are primarily recovered via volumetric kWh-payments
- This also applies for many other industries with high “fixed costs”



Volumetric Rates: Inclining Block Rate Structure

- Inclining Block Rate Structures are most commonly used around the world (including most developing countries)



- Inclining block rates : e.g.
  - 0-100kWh = x/kWh
  - 100-300kWh = y/kWh
  - 300 – 1000kWh = z/kWh

- Inclining block rates make self-consumption more attractive (higher blocks of consumption are erased first)
- Prosumers may also “fall” into lower rate categories, therefore paying a lower per-kWh price

Volumetric Rates: Inclining Block Rate Structure

- China: Zhejiang Province
  - Steeply inclining blocks, with zero customer charge

Zhejiang Province Rates		
Annual Usage	Equivalent monthly usage	$ per Kwh
<2.760	<230	0.087
2761 - 4800	230 - 400	0.09
>4800	>400	0.136

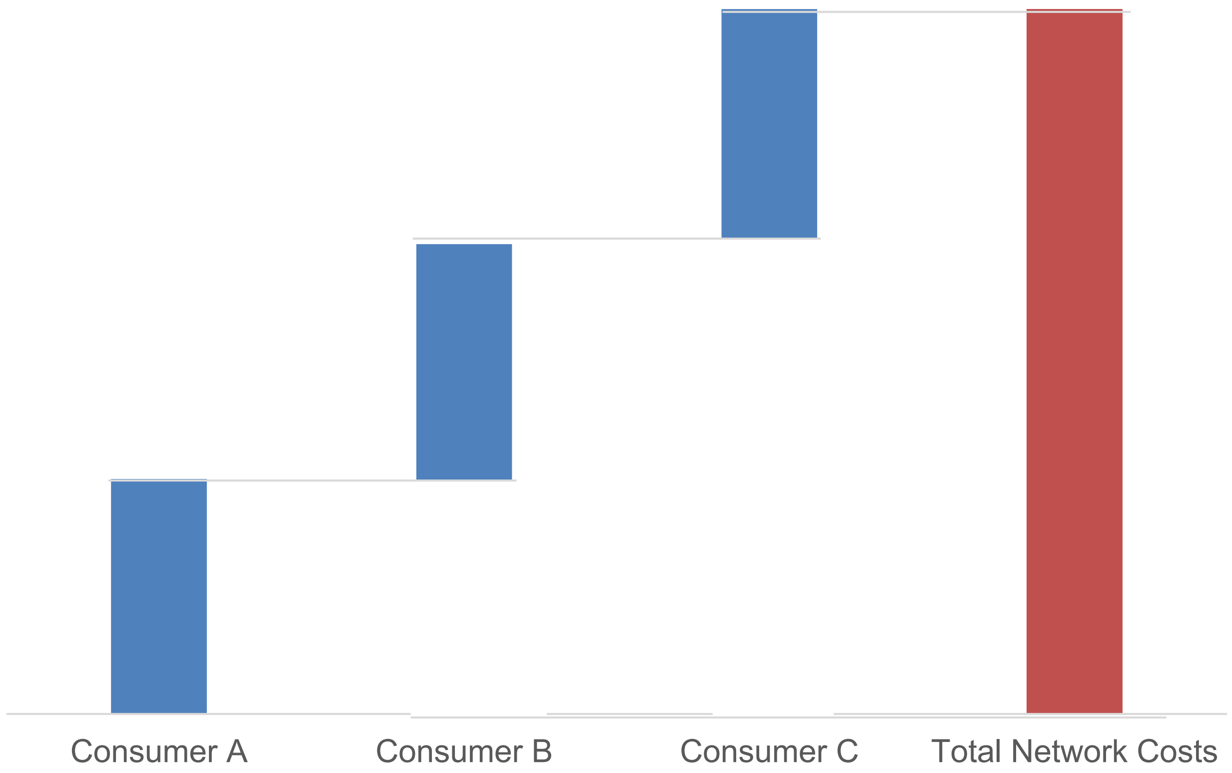
Source: RAPonline, 2013

- Inclining block rate structures can also help to reduce peak load to a certain extent and provide incentives for energy efficiency

Volumetric Rates: Advantages

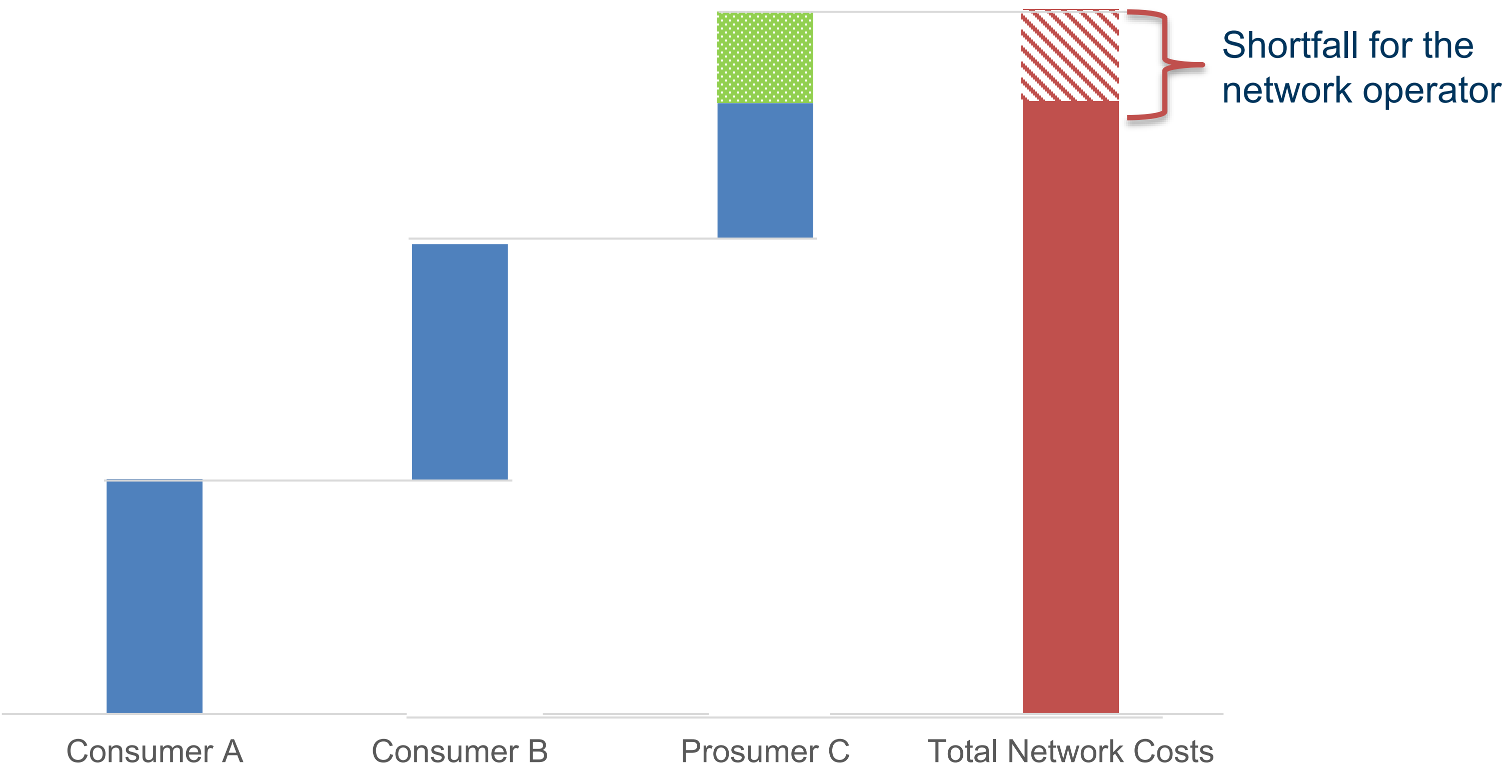
- **Simple** to understand for consumers
- **Affordable** for low-income households (they usually consume less electricity and thus also pay less).
- **Fairness**: Distribution grid costs are primarily driven by peak demand (caused by high usage customers and not low-income households in multi-family houses)
- Implicit **incentive for energy efficiency** (and peak-time reduction in the case of time-based rates).
- Create **incentives for prosumers** (reduce total costs with a reduction of electricity drawn from the grid)

Volumetric Rates: Network Costs and Prosumers



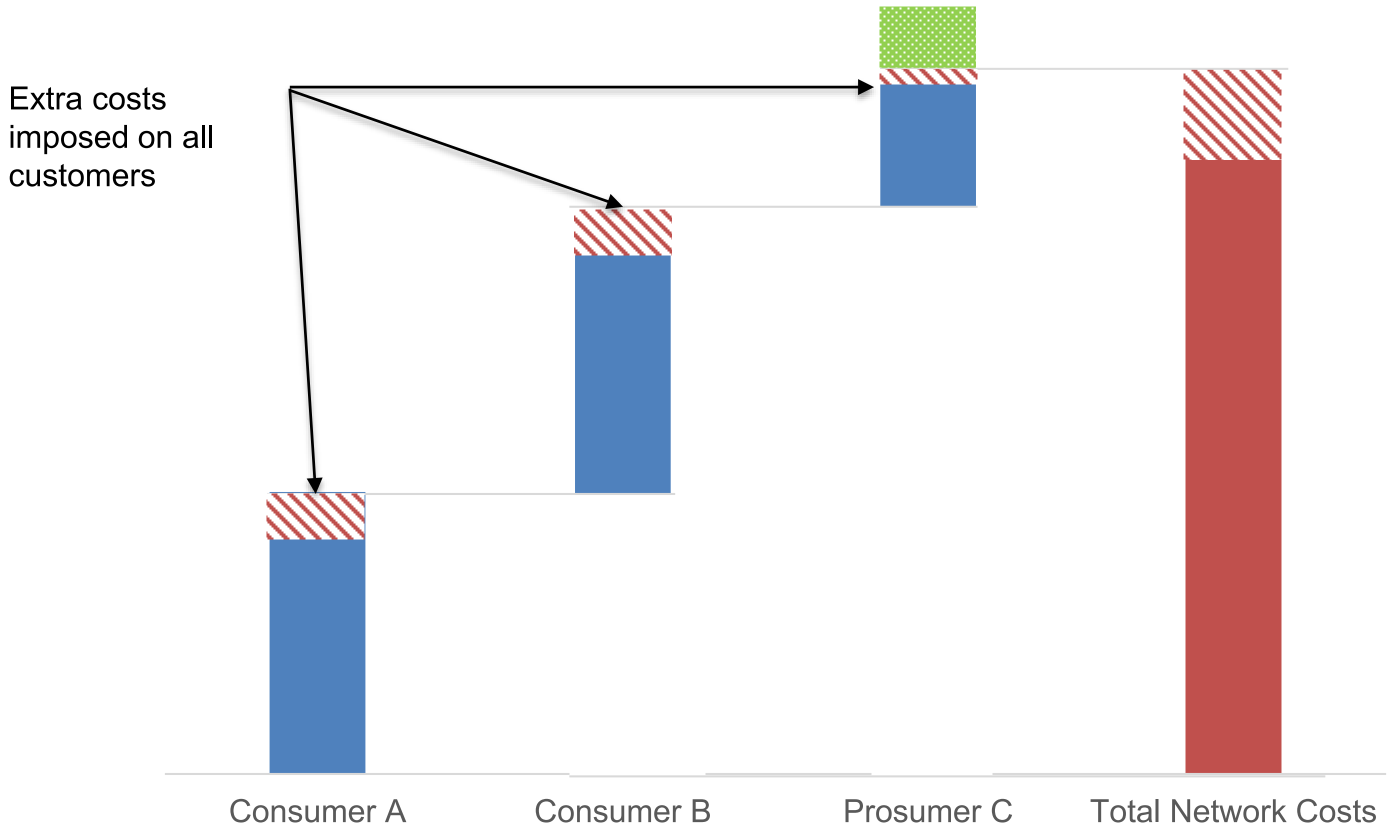
Source: IET

Volumetric Rates: Network Costs and Prosumers



Source: IET

Volumetric Rates:
Network Costs and Prosumers



Source: IET

Volumetric Rates: Disadvantages

- **Cost recovery** for utilities/network operators is more risky
- Common concerns emerge over "cross-subsidization" and the (under-) recovery of fixed (i.e. non energy-related) system costs
- Prosumers **might not pay their "fair share"** for the grid infrastructure and put additional burden on non-prosumers
  - Major argument in developing countries where roof-mounted PV is frequently perceived as "rich guys business"

Volumetric Rates: Network Costs and Prosumers

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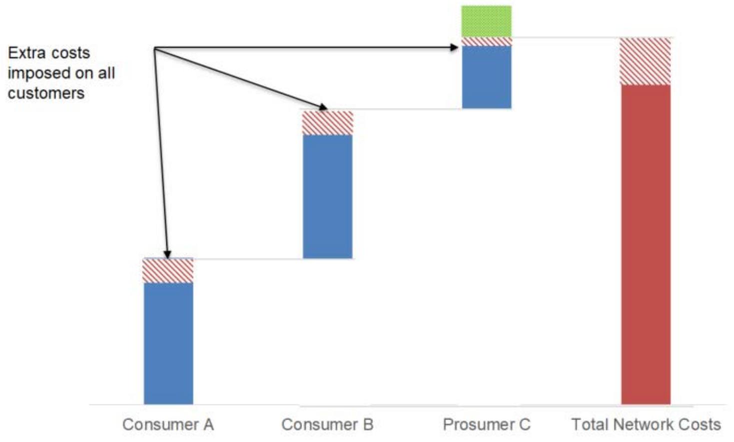
- **However:**
  - Impact of prosumerism is negligible at start.
  - Residential and (small)commercial customers only constitute a certain share of total demand (and system costs)
  - Cost of prosumers need to be compared with benefits
  - Other policy objectives need to be take into account (not exclusive focus on "cost causation").



Source: IET

Traditional Rate Design:

Fixed Charges

Fixed Charges ($/kW PV Installed)

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- Utilities argue that prosumers are using the existing electricity grid as a storage unit and not paying their fair share:
  - Argue that they should also contribute to supporting the overall costs of maintaining the electricity network infrastructure

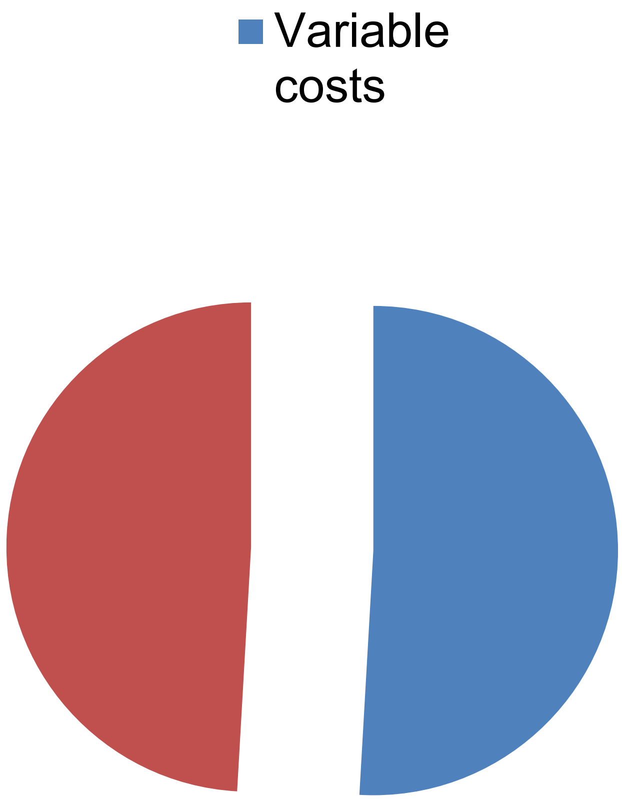
- Higher fixed charges are frequently put forward as a straightforward solution to the problem:
  - The revenues from the fixed charges will allow the utility to cover the fixed system costs related to network infrastructure

- This charge is typically imposed on prosumers as a $/kW/month fee for each kW of installed solar capacity

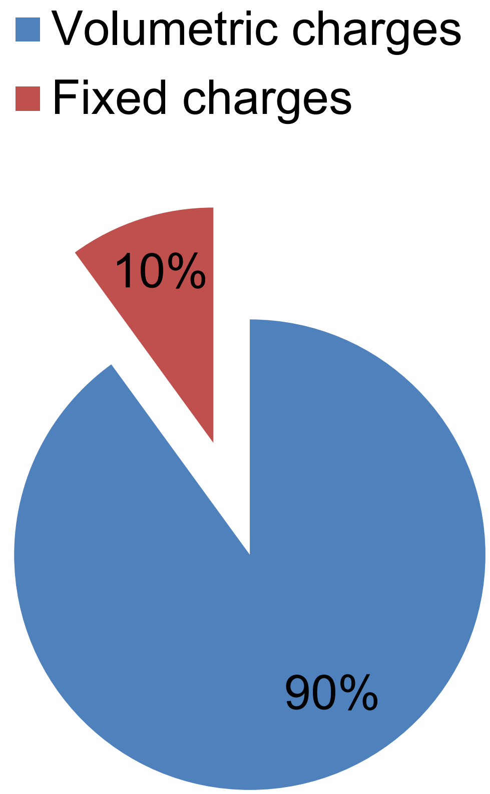
- Sometimes imposed on all customers

Fixed Charges: Are most (utility/ network) Costs Fixed?

Short-term utility cost structure



Typical composition of residential bills



Source: IET, adopted from APPA (2015)

Remember emerging objective:

- Adopts **long-term perspective** when assessing which costs are fixed (and which variable)

Fixed Charges: Advantages

- **Simple cost recovery** for the utility/network operator.
- Enforcing the **cost causation** principle by fixed charges on prosumers
- Advantage for customers with **high electricity demand** (cross-subsidy from low-demand customers).

Fixed Charges: Disadvantages Challenges

- **Reduced** incentive for system-wide **efficiency**
  - Increased electricity system costs
  - Incentive to over-built power generation capacity (planning no longer based on marginal costs).

- **Reduced** incentive for **system flexibility**:
  - Fixed charges do not send a price signal to consumers and, as such, do not incentivise behavioural adjustments
  - Existing price signals are undermined

Fixed Charges: Disadvantages Challenges

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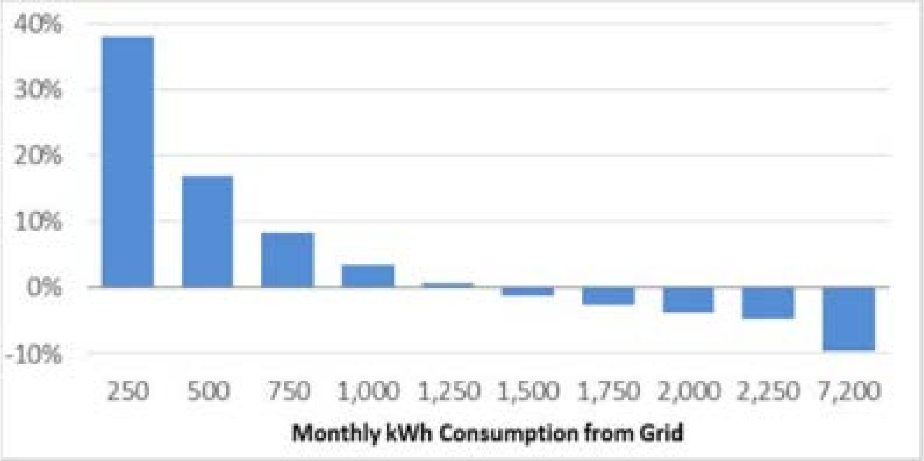
- **Disincentive for energy efficiency** and others:
  - Higher fixed charges can reduce incentives to reduce consumption through energy efficiency, distributed generation, or other means
  - ments in energy efficiency measures or distributed generation will have longer payback periods.
  - Negatively impact the economics of “going solar” (advantages of DG ist not taken sufficiently into account – cost-benefit analysis).

- **Disincentive for new technologies**: Unfairly penalize solar system owners (why not introduce a fixed charge for insulating your home, or efficient AC units?)

Fixed Charges: Disadvantages

- Customers who use less energy than average experience the steepest increase in their electric bills every time the fixed charge is raised (see Figure below)
- Place a higher **burden on low-income households**

Increase in average monthly bill



Analysis based on increasing the fixed charge from $9/month to $25/month, with a corresponding decrease in the $/kWh charge (EIA Data, table from Synapse Energy, 2016)

Traditional Rate Design:

Minimum Bills

Minimum Bills: Examples

Country/ Jurisdiction	Minimum bill
California	Charges are billed as daily minimum meter charges and are meant to help utilities cover fixed costs for transmission, distribution, billing and metering. **Minimum bills were increased from $1.79 – 4.50 USD to 10 USD** for month for all customers and capped at **$5 USD for low income customer classes**. Future proposed minimum bill and/or fixed customer charge amounts are subject to review.
Hawaii	In Hawaii, HECO, HELCO, and MECO apply minimum charges for their single-phase and three-phase customers. Single-phase customers face a minimum charge of USD $17 – $20.50 per month, while three-phase customers face a **minimum charge of $22.50 – 25.00**.

Traditional Rate Design:

Demand Charges ($/kW of peak demand)

Demand Charges: $/kW

- Demand-based rates are a special charge levied on electricity customers **based on their peak electricity demand** over a previous period of time (typically annual): calculated based on the **interval with the highest kW usage within a billing period**.

- Traditionally levied on large **commercial and industrial customers**: increasingly discussed as a rate option for residential customers as well

- Historically, residential customers have been less equipped to monitor real-time demand and respond to pricing signals, etc. than commercial and industrial customers

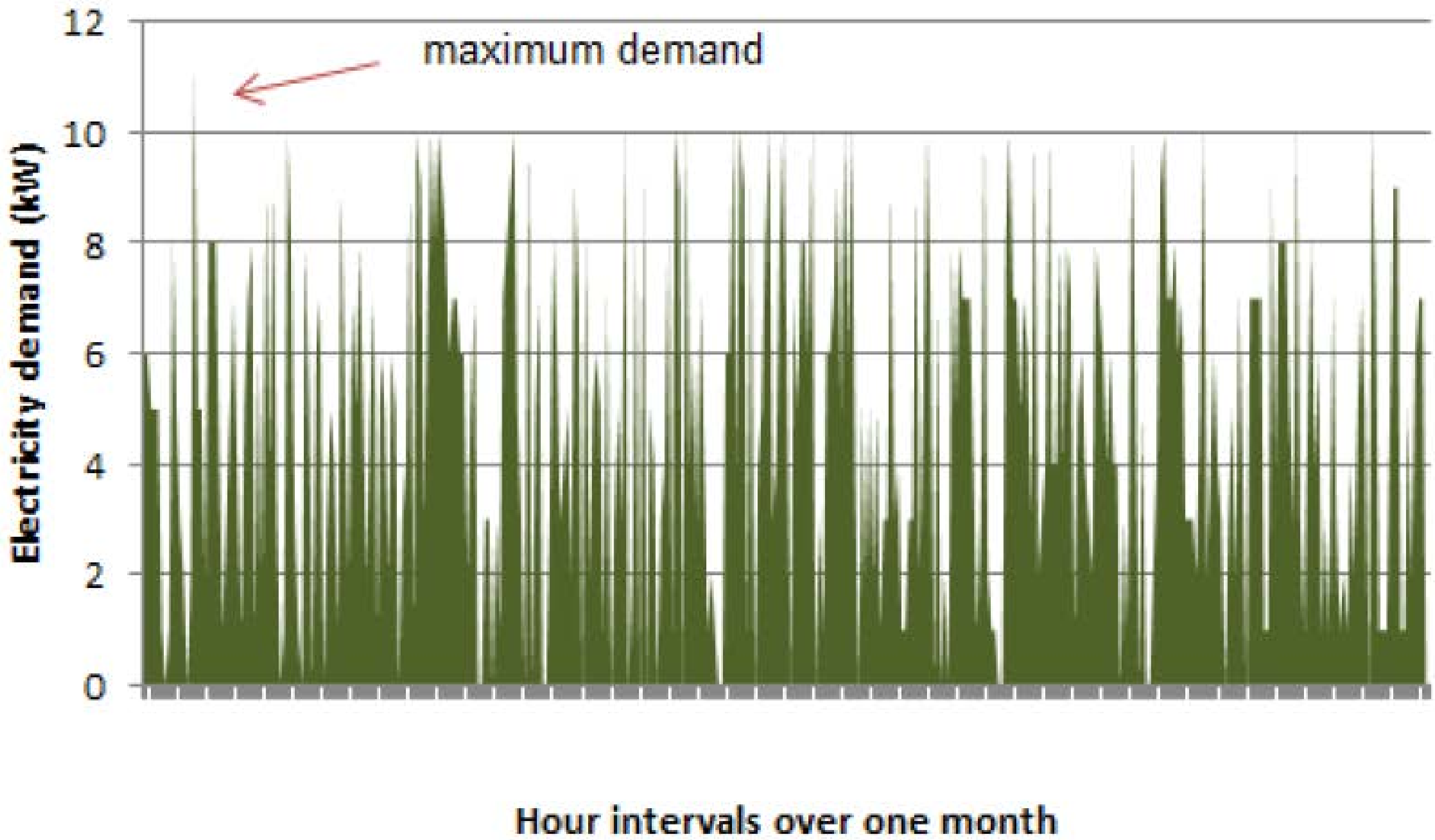
Demand Charges: $/kW

- How demand charges are calculated:

- “First, the **interval with the maximum capacity demanded is identified**. The capacity within that interval is then typically averaged. To derive the demand charge component of the rate, the average capacity for the interval is **multiplied by the utility’s demand charge rate** for the time of day/season in which the interval occurred.
- For example, given a maximum capacity demand of 11kW and a demand charge of $5/kW, the demand charge component for the monthly bill would be (11*5)=$55.”

Source: Bird et al. http://www.nrel.gov/docs/fy15osti/64850.pdf

Demand Charges: $/kW



Demand Charges: $/kW

Typical Commercial Rate with Demand Charges		
Rate element	**Illustrative Rate**	**Application**
Fixed Charge	12 USD/month	Independent of usage
Demand Charge	15/kW USD	Customer's highest 1-hour usage per months
Volumetric Charge	0.10/kWh USD	For each unit (kWh)

Source: IET based on Lazar, J. and W. Gonzalez (2015)

Demand Charges: Advantages

- **Cost Causation**: Prosumers will likely have to pay higher demand charges if PV generation does not coincide with their peak demand (e.g. peak demand during the winter). This way, they will contribute to total system costs.

- Demand charges can reduce peak demand and thus lower total electricity system costs (**system efficiency**).

Demand Charges: Disadvantages

- **Simplicity**: Demand charges are relatively complex and difficult to understand for residential customers
- Demand-control technologies are usually not readily available for residential and small commercial customers
- **Fairness**: Demand charges for residential customers and small businesses might be disproportional since their peak demand does to coincide with system peak demand
- **Flexibility/Cost Efficiency**: Demand charges hinder flexibility (no incentive to "consume more" in times of excess RE power generation)
  - This only applies for power systems with very high shares of VRE.

Source: IET based on Chernick et al. 201

Outlook:

Smart Rate Design for a Prosumer World

An Extended Overview of Rate Design Options

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Traditional rates	Smart rates	Prosumer rates
• Volumetric Charges • Fixed Charges • Minimum bills • Demand Charges	• Time-of-Use • Real-Time Pricing • Locational Pricing	• Two-way rates • Specific rates for prosumers
Can be implemented based on **existing meter technologies**	Require **advanced metering infrastructure (AMI)**	

Source: IET based on Cross-Call, D., et al. (2018), Linvill 2014

Further Reading/List of References

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Further Reading: Rate Design and Distributed Generation (PV)

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Thank you for your time!

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6. Knowledge Checkpoint: Multiple Choice Questions